
1994 RESEARCH HIGHLIGHTS



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**Air Force Office of Scientific Research
Bolling AFB DC 20332-0001**

Preface

This volume is the second annual issue of *Research Highlights* based on our monthly collection of significant achievements and accomplishments. Although this edition contains only a small selection of AFOSR's many research successes in 1993, the highlights are representative of our mission to "sponsor and sustain basic research, to transfer and transition research results, and to support Air Force goals of control and maximum utilization of air and space." The highlights provide brief descriptions of research accomplishments, examples of technology transfer, technology insertion, and dual-use applications.

It is a well-documented historical fact that basic research has always been important to the Air Force in maintaining its technological edge. Maintaining this edge has become even more crucial today as the Air Force faces the challenges and uncertainties of the emerging new world order and the fundamental reshaping of the Air Force itself. Some of the research highlighted here has been "transitioned" to the developmental research phase while others have found their way into Air Force systems. In fiscal year 93 alone, there were more than 160 significant transitions from basic research to applications. Other examples will not reach maturity until the 21st century. Some of the research featured here will also contribute to dual-use technology in the civilian sector. The diverse and wide-ranging scientific efforts in this volume share the common denominator of quality research. They are also evidence of how, in consonance with its motto "Building Partnerships With Excellence and Relevance," AFOSR continues to fulfill its important role as a technology transition broker. AFOSR will continue to provide the Nation with the basic knowledge for new and advanced technologies to meet the challenges of the future.

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Directorate of Aerospace and Engineering Sciences

New Test Facility to Save Millions in Hypersonic Missile Testing

Researchers working at the Calspan-University of Buffalo Research Center recently completed construction of the Large Energy National Shock tunnel (LENS). The tunnel is the first facility of its kind in the world and is capable of duplicating the flight environment that a hypersonic missile interceptor encounters. Before construction of the facility, the only way to obtain aero-optic boresight error, jitter, and attenuation data on interceptor flights involved costly full-scale tests. The new tunnel will allow the Air Force to save millions of dollars in designing future hypersonic missile systems.

The tunnel is capable of routinely operating at conditions which duplicate and not merely simulate actual flight environment (flight total temperatures and Reynolds numbers). The LENS can be operated at pressures as high as 40,000 pounds per square inch and total temperatures up to 14,000 degrees Rankine. The test section of the tunnel is over four feet in diameter, which allows the testing of full-scale flight vehicle configurations.

Preliminary missile tests measured the actual signal attenuation and recorded the signal image received by the interceptor. Research using the new tunnel will investigate the effects of compressible turbulence and finite-rate chemistry on aero-optic phenomena such as boresight error and signal attenuation.

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High-Temperature Metal Reaction Studies Offer Advanced Propellants, Civilian Spinoffs

Dr. Arthur Fontijn and his research group at the Rensselaer Polytechnic Institute have developed new techniques to study high-temperature metal reaction rates. The Phillips Laboratory is using their research results on the combustion rates of aluminum and boron to design advanced solid propellants to fuel missiles and space boosters. The application of this research will allow the Air Force to develop the capability to lift heavier payloads with the same or smaller propellant mass and to produce environmentally-cleaner rocket exhausts.

Working with Phillips Laboratory scientists, the Rensselaer group provided experimental data over wide temperature ranges of aluminum and boron reactions. The large temperature ranges are necessary since existing theory is not capable of predicting the influence of temperature on the

rates of these chemical reactions. The reaction rate information is used by the Air Force to model the effects that additive and composition changes have on propellant performance.

Their research will also have other military applications. Understanding the high-temperature reactions of metals will prevent hot corrosion and alleviate soot formation in jet engine turbines, and allow new chemical synthesis processes for refractory materials.

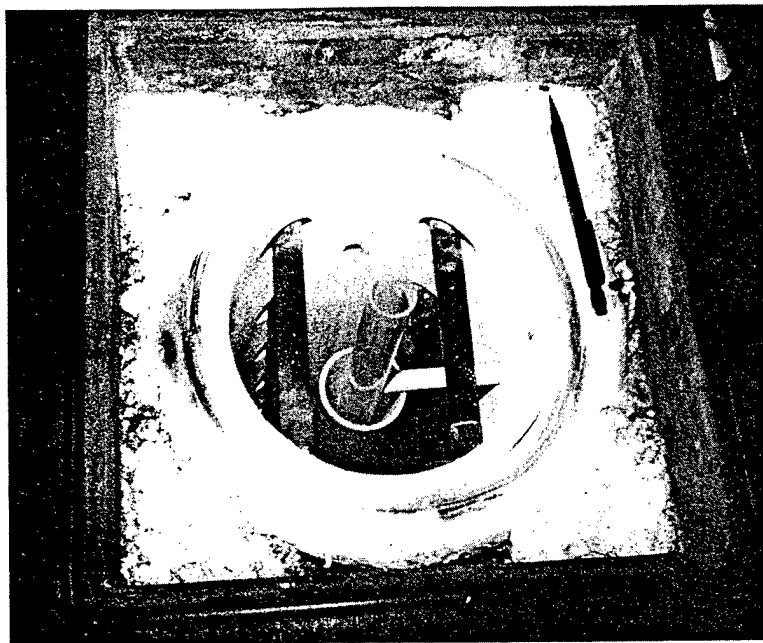


Figure 1. The Air Force is using research results on the combustion rates of aluminum and boron to design advanced solid propellants to fuel missiles and space boosters. This figure shows an inside top view of the High-Temperature Fast-Flow Reactor used by the RPI group to determine reaction rates. From the outside in, the photograph shows the vacuum housing layers, heating rods, and reaction tube. The pencil, at right, shows the size of the apparatus.

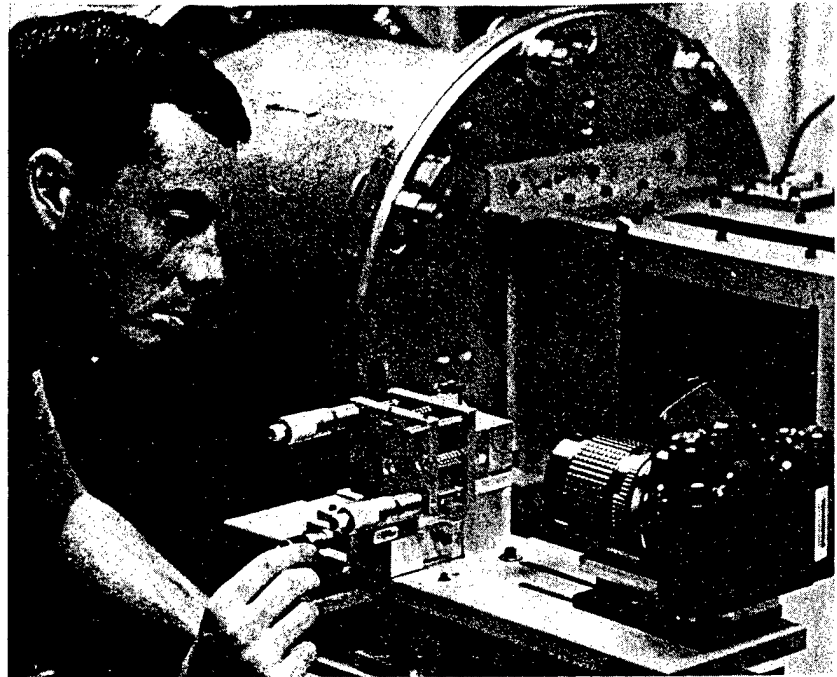
The research will spinoff for civilian applications. The studies conducted by Dr. Fontijn's group led to the discovery of the direct gaseous metal oxide reaction with methane which converts natural gas to liquid fuels and chemicals which is of major interest to the petroleum industry. They were also able to eliminate the highly toxic state of chromium oxide, a major problem in municipal solid waste incinerators. Dr. Fontijn's new book, *Gas-Phase Metal Reactions*, will serve as an excellent guide for both military and civilian applications of his techniques.

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Fluid Dynamics Research May Enhance Aircraft Maneuverability

Florida A&M and Florida State Universities are conducting basic research to address aerodynamic phenomena associated with high angle of attack flight. The unsteady aerodynamic flow around both the airframe and the control surfaces in this flight regime is a major cause of structural fatigue and flight instability problems. However, if properly controlled and understood, unsteady aerodynamic flows may also be beneficial to increase lift, delay stall and enhance aircraft maneuverability.

Figure 2. A basic research program at Florida State University will help the Air Force better understand and control the unsteady aerodynamics associated with high angle of attack flight. Maj. William Crisler, an Air Force Ph.D. candidate at the university, conducts research on the university's transonic wind tunnel facility. He is adjusting the Particle Image Velocimetry (PIV) photographic apparatus which will be used to take instantaneous snapshots of the unsteady, high-speed flowfield.



Experimentally, the researchers have developed a Particle Image Velocimetry (PIV) system along with new laser diagnostics to analyze complex, high-speed flows over two-dimensional surfaces. They recently extended this technique to three dimensions by devising an innovative holographic PIV set-up. This capability will allow them to obtain instantaneous velocity and vorticity fields in selected regions of unsteady three-dimensional flows. This new technique is of interest to universities, Air Force laboratories and industry to aid verification of detailed computational results and to uncover new flow topologies. This will enable effective control strategies to safely maneuver in this unsteady regime.

Computationally, the researchers combined high Reynolds number theory with a three-dimensional gridless algorithm for unsteady flows that extends their computations to realistic flow speeds while allowing for compressibility and shock effects. They have combined these unique tools to propose a new research area that couples unsteady aerodynamics with thrust vectoring control systems for effective and efficient maneuvering well into the post-stall high angle of attack flight regime.

This one-of-a-kind collaborative effort was originated and funded by the Historically Black College and Universities and Minority Institutions program at AFOSR, with some partial support from ARPA.

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NASP Scramjet Design Benefits From New Laser Diagnostic Technique

Professor Ron Hanson of Stanford University has developed a new diagnostic tool which has been adopted by the National Aerospace Plane (NASP) Joint Program Office (JPO) for optimizing scramjet engine designs needed for hypersonic flight. Future Air Force mission applications for this new technique include high-speed reconnaissance aircraft, manned interceptors and missile propulsion systems.

The NASP office recently installed the new on-line spectroscopic measurement technique for oxygen and water vapor at the NASA Ames 0.4 meter (16 inch) shock tunnel which they will use for scramjet performance tests. The measurement technique is based on the use of diode lasers with superior wavelength and modal properties. These properties make it possible to simultaneously measure multiple gasdynamic properties and chemical species in hypersonic flow test facilities through the attenuation of the laser beam by absorption and at points along the laser beam by laser-induced fluorescence.

Use of the new tool creates two benefits:

- 1) the laser's low cost, compactness and durability allows the technique to be used in hostile testing environments such as aircraft combustors or jet engine nozzles, and
- 2) the absorption spectroscopy technique will enable combined measurements of propulsion parameters by providing simultaneous data on such parameters as the air mass flux entering the combustor and the combustion efficiency.

The JPO plans to use the water absorption measurement to determine combustion efficiency for flight testing. This will be a significant milestone, marking the first application of spectroscopic measurement capability for flight-rated test and evaluation instrumentation.

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Scientists Develop Experimental Method to Reduce Airfield Maintenance Costs

Wright Laboratory scientists Drs. Jeffrey Rish, Xiaogong Lee, and William Dass have developed an experimental method to characterize the internal packing structure of particulate material systems. Initially, this method will be used to examine the mechanisms that control rutting in asphalt concrete runways caused by high-pressure, high-gross load tires used on the current generation of fighters. Remedial and design strategies developed from this knowledge will reduce airfield maintenance costs by 40 percent. At this rate, the Air Force is expected to save \$40 million in maintenance costs by 1999.

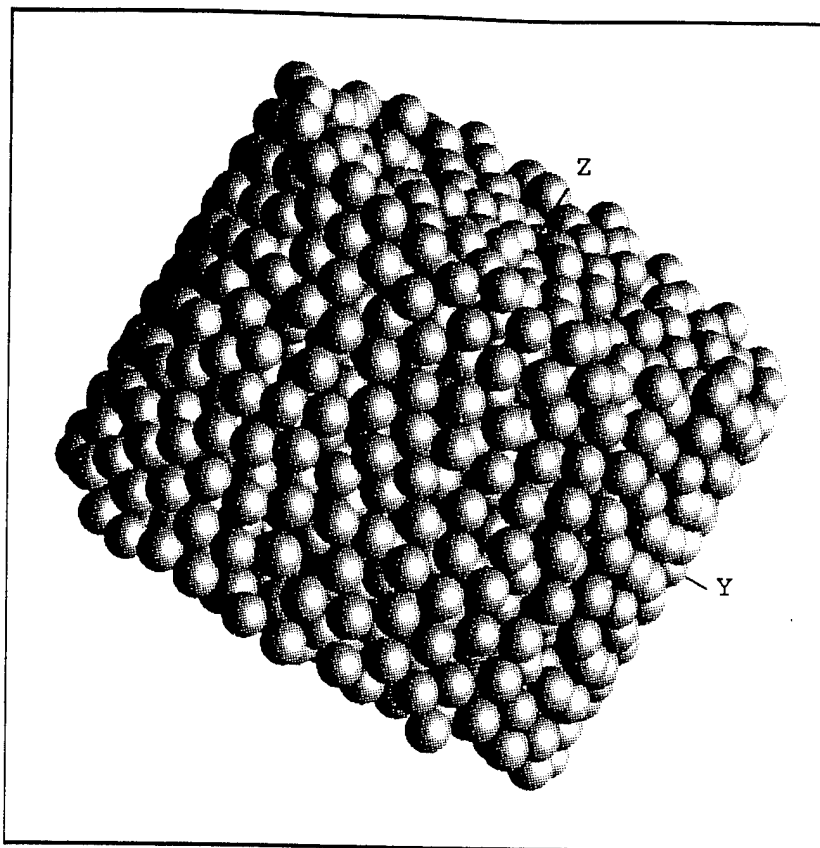


Figure 3. Airfield maintenance costs could be reduced by 40 percent (\$40 million by 1999) through use of the Wright Laboratory's new experimental method to examine the mechanisms that control rutting in asphalt concrete runways. The new method characterizes the internal packing structures of particulate material systems. This three-dimensional view of a packing structure composed of six millimeter glass beads with eight percent by weight asphalt cement is representative of the structures tested by the researchers.

This new method makes it possible to determine the microstructural parameters which control the behavior of particulate materials directly from material specimens as opposed to computer-based numerical models. The specific parameters include volume fractions, particle arrangement, contact geometry, and structural evolution under changing loads. The method uses an industrial, high-resolution X-ray computerized tomography (CT) machine to "non-intrusively" obtain cross-sectional images of the specimens. New image processing algorithms are used to reconstruct full three-dimensional structures from the CT cross-sectional images. A special loading device which fits on the CT machine platform allows investigators to observe changes in the internal structure of a specimen with subsequent increases in loading, a capability not previously available.

In the initial tests using a particulate system composed of six millimeter laboratory-packed glass beads mixed with asphalt cement, the changes in the specimen's internal packing structure were clearly observed and the image resolution was clear enough to accurately identify the structure of the asphalt binder.

The method can be used to study the microstructural behavior of other particulate systems including solid-rocket propellants, advanced materials for future aerospace systems, and other materials common to both the DOD and the private sector.

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New Optical Diagnostic Technique Offers Advances in Jet Engine Design

Dr. Richard K. Chang of Yale University, working under AFOSR's diagnostics program, has developed a new optical diagnostic technique to measure small changes in liquid droplet radius information. This information is critical to the understanding of spray dynamics that control the performance of the aircraft engine combustion process. This diagnostic technique will be used to design high-performance, low-pollutant jet engines for the Air Force.

Professor Chang's technique is based on a high quality, minimum light leakage optical cavity and provides sharp peaks in the elastic scattering spectrum. The peaks can be used as an optical template to provide real-time droplet diameter information. The optical template has been used extensively in injector design by the gas turbine and rocket industries. It can also be used as a diameter-determining template for optical communication fiber during the fiber-melt pulling process to continuously monitor the fiber's outer diameter. Dr. Chang is also developing a real-time, shape distortion optical technique that will be used in the fiber optic industry to monitor "out-of-round" cylindrical distortions of fiber.

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Idea Surfaced at Research Review Leads to Life Extension of F-110-GE Engine

The F-110-GE engine which powers the F-16 aircraft proved to have a shorter life than desired due to unanticipated changes in usage resulting from its superior performance and operability. However, a senior engine systems engineer from Aeronautical Systems Center's (ASC) Engineering Directorate uncovered a solution to this problem during a review of propulsion research projects jointly sponsored by AFOSR's Directorate of Aerospace and Engineering Sciences and the MIT Gas Turbine Laboratory. The engineer attended the review to discuss specific research issues related to field and developmental systems. A discussion of MIT's work dealing with the active control of compression system instabilities triggered the idea for a control methodology that would extend the life of the F-110-GE engine. This idea led to the successful development of new control methods in the F-110-GE which are estimated to extend its life by 17 percent, save \$15 million a year, increase the availability of the engine and reduce spare parts requirements.

The ongoing MIT interdisciplinary work on the control of compression system instabilities through adaptive engine control systems promises significant future applications. The ASC research problem addressed at the review meeting involved the existing analog system for pressure ratio control on the F-110-GE engine which resulted in large rotor speed variations to change the desired thrust level. After discussing this control problem at the AFOSR-MIT review, ASC

established a project under the component improvement program to develop digital control and control schedules that used alternate methods for thrust control that minimized rotor speed excursions and extended engine life. The F-16 program office has supported the retrofit incorporating this new control system and the development program has recently completed flight test.

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Directorate of Chemistry and Materials Sciences

New Synthetic Polymer Contributes to Development of Flat-Panel Color Displays

Professor Frank Karasz of the University of Massachusetts at Amherst has successfully synthesized a new polymer that will allow "high definition" information to be seen on flat-panel displays. This type of display will have an advantage over conventional cathode ray tube technology due to its light weight and reduced volume, important features in environments such as aircraft cockpits. Unlike existing liquid crystalline displays, flat-panels will have a wide angle of view. His discovery represents an important milestone in the effort to develop flat-panel color displays for military and commercial applications in command, control, communications and intelligence (C³I).

Professor Karasz' accomplishment involves the successful synthesis of an electroluminescent polymer, p-phenylene vinylene (PPV), that enables the fabrication of a blue-light emitting diode (LED) structure. This is possibly the first reported blue emitter in a polymer LED that uses a solution processible macromolecule. The blue emitter, together with the red and green type, will enable the presentation of full color information in a closed-in environment.

Scientists consider electroluminescent polymers a better material than inorganic semiconductors and organic crystals for use in flat-panel displays because of their potential for quantum efficiency in all wavelengths, long-term stability and low fabrication costs for large-scale devices. Since a Cambridge University group first reported an electroluminescent polymer that emitted green-yellow light, many research groups around the world have been attempting to generate a blue-light emitting polymer. Most of these efforts focused on changing the chemical structures of the polymers to yield larger "band gap" electronic structures, but the Karasz group elected to increase the band gap by controlling the conjugation length of the PPV units. Their highly technical, innovative approach to solving the problem brought a polymer based, low-cost flat-panel color display a step closer to reality.

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Computer Code Developed to Simulate Spacecraft Contamination

The Air Force's Phillips Laboratory has developed a new computer code named SOCRATES to simulate the contamination of spacecraft during flight. The instruments on space platforms become contaminated when gases which have evaporated (outgassed) from the spacecraft or have

been released during thruster firings, interact with the surrounding gases in space and are deposited on the instruments. By simulating the contamination, improved mission procedures can be developed and spacecraft can be designed to minimize contamination. The first module of the code, developed by a group at Phillips Laboratory under the direction of Dr. Edmond Murad, was recently demonstrated for the Air Force Space Command where it will be installed as an integral part of a satellite tracking network. SOCRATES will be applicable to both military and civilian space systems.

The first module of the SOCRATES code focuses on the interactions and reactions of the gases around the spacecraft. These interactions deposit contaminants on the spacecraft, create luminous backgrounds, and erode exposed surfaces which degrade sensor performance, affect satellite signatures, and interfere with space-borne measurements.

SOCRATES is a predictive code and uses many rate constants for the reactions of neutral and ionic species which were originally measured in AFOSR-sponsored research. Future modules of the code will model how gases interact and react with spacecraft surfaces.

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Improved Method of Processing Aromatic Polymers Developed

Dr. Fred E. Arnold, a Wright Laboratory Materials Directorate Research Fellow, has discovered a new process which has greatly advanced the chemistry of heterocyclic aromatic polymers (cyclic structures that include atoms other than carbon and hydrogen). Air Force applications include organic matrix composite engine parts and high speed electronics packaging.

Because of their electronic conjugation, heterocyclic aromatic polymers have several excellent features including good thermal stability, large nonresonant nonlinear optical properties and excellent mechanical strength. Many advanced materials like high-performance fiber, conductive polymers, nonlinear optical thin films, high-temperature insulation, and dielectric thin films are based on this class of chemistry. However, heterocyclic aromatic polymers are very difficult to process. They are typically fabricated through the use of high-boiling aprotic (a solvent that does not yield or accept a proton) or corrosive solvents.

During the course of their research in the structural tailoring of heterocyclic aromatic polymers, Dr. Arnold and his coworkers at the University of Dayton Research Institute discovered a novel scheme to make heterocyclic polymers soluble in low-boiling, common solvents like methanol. The process involves adding triethylamine to the methanolic slurries resulting in instantaneous solubility. Highly concentrated solutions can be obtained through this approach.

Arnold's discovery opens up numerous processing options for this class of polymers. Processing schemes such as spin-coating for optical and electronic applications and fiber impregnation for structural composite applications are now possible.

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Research Improves Stability of Electro-Optic Polymeric Thin Films

Research conducted by Professor Larry Dalton and his team at the University of Southern California has led to a significant breakthrough in the long term stability of electro-optic polymeric thin films. The absence of long term stability in polymeric materials has severely limited their use in optoelectronics research for high-speed communications and data processing. The Dalton team's advance in materials synthesis and processing has produced a material system which can be developed into device grade material for the fabrication of high-frequency modulators for Air Force optical communication applications. These modulators will make high-speed, large bandwidth communications possible.

Professor Dalton and his fellow researchers succeeded in preparing thermally stable polymeric thin films with a very high non-resonant, electro-optic coefficient. Other researchers have reported larger electro-optic coefficients, but the Dalton team's work also reflects 100 percent retention of nonlinear optical activity after exposure to 100°C temperatures for 1000 hours. This fact can be translated into years of stability at operating temperatures of 30-40°C. The researchers accomplished the improved thermal stability through the optimization of the polymer "backbone" structure and by careful choice of chromophores to maximize their weight fraction in the system while retaining a high glass transition temperature for the polymer matrix. A double crosslinking scheme, effected by judicious modification of the chromophore monomers, facilitated the "locking in" of the chromophore orientation with chemical bonds and thus the retention of long-term stability of the electro-optic coefficient.

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Potential Damage to Aerospace Structures Discovered

In a collaborative effort, Professor Ralph Mitchell of Harvard University and Ms. Katie Thorp of the University of Dayton Research Institute have discovered the potential for biologically- induced damage to polymeric composites. Microorganisms are known to cause the degradation of ad-

vanced composite resins, but this was thought to be a surface effect that could be prevented by protective coatings.

Mitchell and Thorp found that the porous interfaces between composite resin and fiber are colonized by microorganisms. This discovery indicates the potential breakdown of this critical interface by chemical and mechanical mechanisms and the masking of damage during nondestructive evaluation. This finding may impact the life cycle of these composites which are being increasingly used in primary structural applications on Air Force aircraft and missiles. Further understanding of the scope of this phenomenon will provide guidance for preventive measures.

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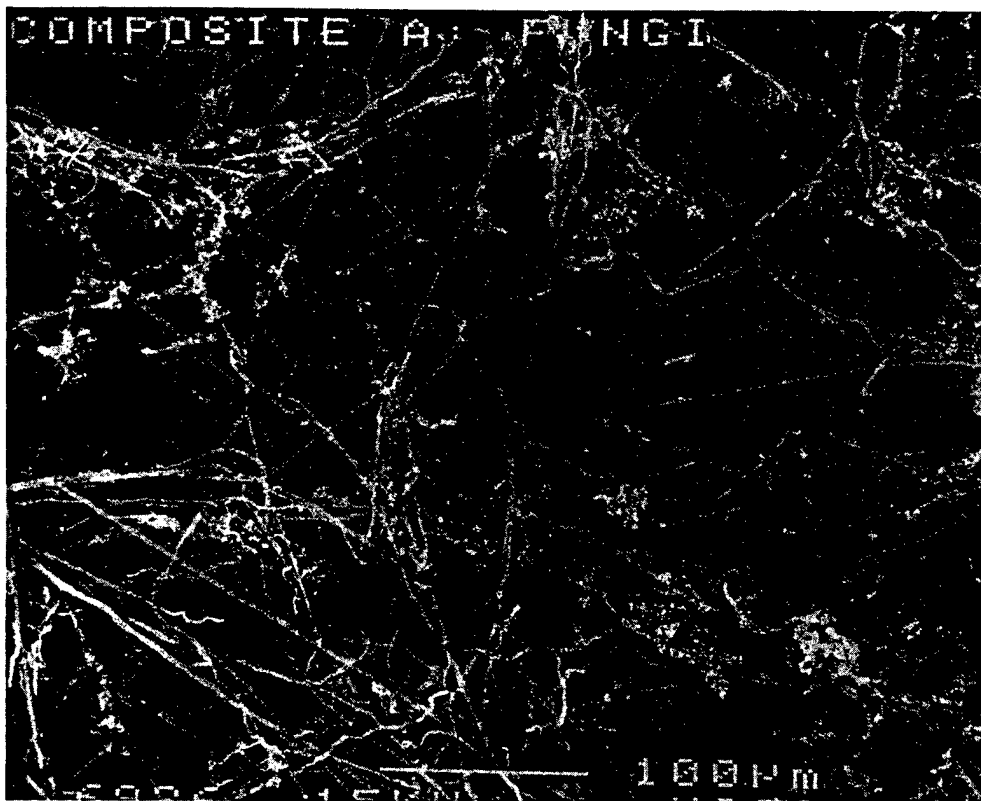


Figure 4. AFOSR researchers discovered microorganisms which are potentially damaging to the porous interfaces between composite resins and fibers. This finding may impact the life cycle of these composites which are increasingly used in primary structural applications on Air Force aircraft. This scanning electron micrograph at 200x magnification shows the degradation of the composites in question.

Directorate of Physics and Electronics Sciences

New Type of Laser Increases Electrical to Optical Conversion Efficiency

Scientists at Photonics Research, Inc. have demonstrated a new laser that incorporates a novel, low resistance, electrically-pumped design capable of emitting in the visible wavelength. Along with the attributes outlined below and combined with the efficiency of the low resistance design, this vertical cavity surface emitting laser (VCSEL) will have applications in many developing Air Force technologies including parallel processing opto-electronics processors; parallel-addressed, high resolution optical disk memory; and visual displays, printers and scanners.

Low internal resistance in the VCSEL reduces the threshold voltage required for lasing and dramatically reduces the amount of heat generated during operation. Low internal resistance also extends the laser's lifetime and enables greater output power without failure. The VCSEL lasers emit aberration-free, circular gaussian beams (as compared to the astigmatic, elliptical gaussian beams of in-plane laser diodes) which require a much less complex optical system design. They can also be fabricated in large two-dimensional arrays on single substrates much more readily than conventional in-plane cavity laser diodes. VCSELs now under development will emit at even shorter wavelengths in the visible spectrum to allow tighter focusing.

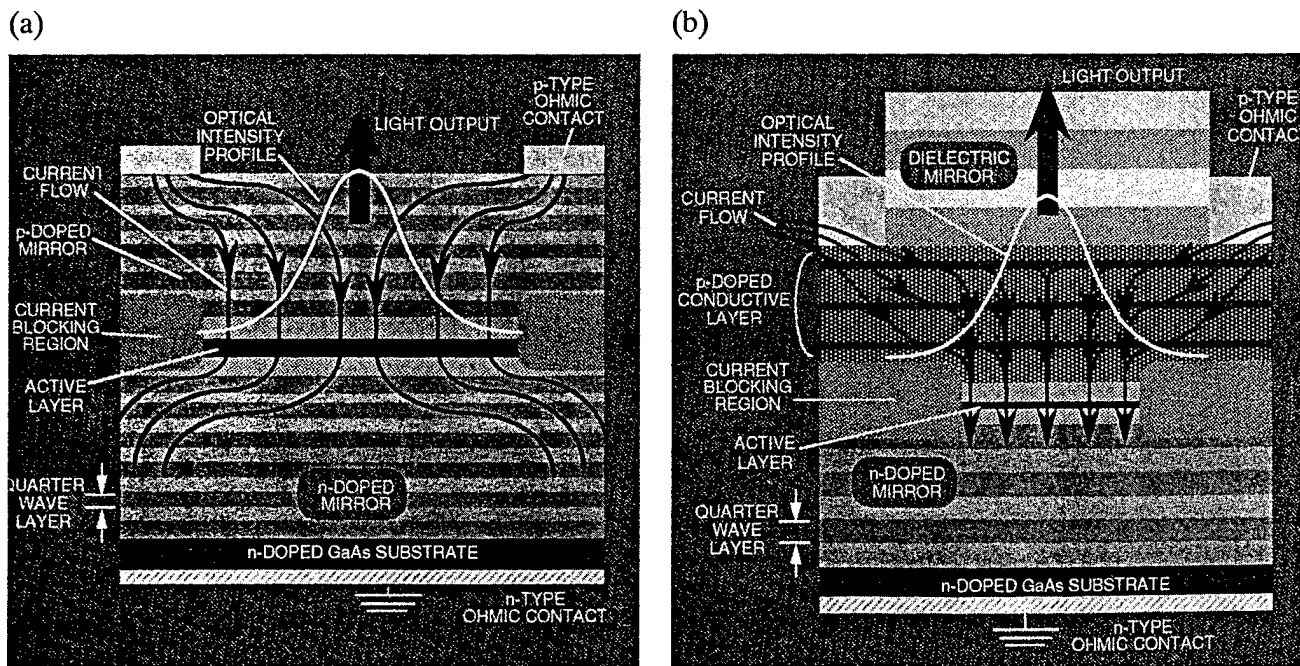


Figure 5. Photonics Research, Inc. scientists have demonstrated a new vertical cavity surface emitting laser (VCSEL) which is much more efficient than existing systems. It will have applications in many developing Air Force technologies and can be used in visual displays, printers, and scanners. The figures compare the electrical pumping geometries between (a) conventional and (b) Photonics Research's high-efficiency VCSEL designs. The researchers completely eliminated the top mirror from the electrical circuit and replaced it with dielectric layers.

To accomplish the substantial improvement in resistance, the Photonics Research investigators redesigned the structure of one of the laser cavity mirrors. They replaced a multiple-layer semiconductor mirror with a dielectric mirror, and arranged the pumping current to pass around the mirror rather than through it. This breakthrough enables wall-plug efficiency (electrical to optical power conversion) of more than 30 percent.

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New Organic Light Emitting Diodes Created to Improve Display Technology

Professor Stephen Forrest and his research group at Princeton University's Center for Photonic and Optoelectronic Materials have successfully demonstrated high brightness red, green, and blue (RGB) crystalline organic, thin film light emitting diodes (LED). These diodes have the potential to fulfill the Air Force's growing need for low cost, full color, flat panel displays. Aircrews and command and control personnel are increasingly called on to quickly interpret and act on a broad range of rapidly available and complex data. Particularly needed are highly visible "heads up" displays which are transparent when inactive, but provide a clearly visible image when turned on, even in bright sunlight. Professor Forrest's work was the first successful demonstration with

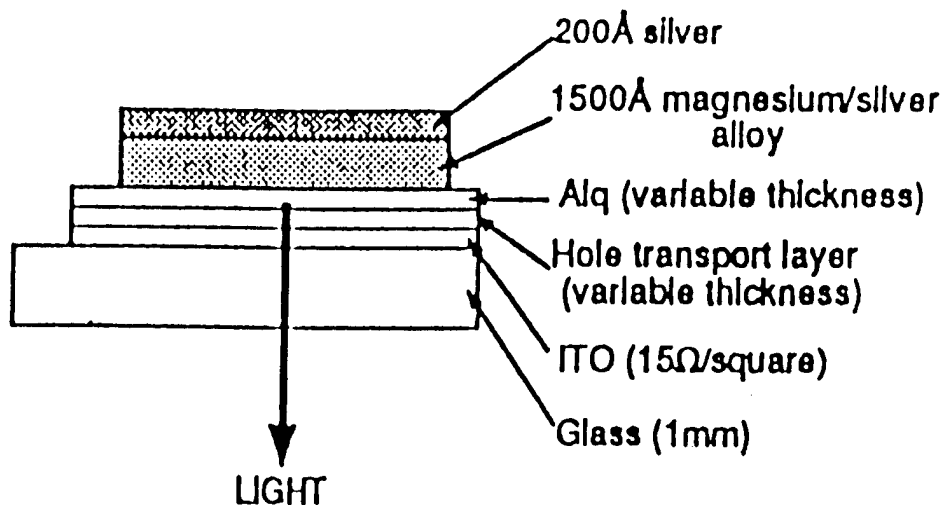


Figure 6. Thin film light emitting diodes (LED) developed by a research group at Princeton's Center for Photonic and Optoelectronic Materials have the potential to fulfill the Air Force's growing need for low cost, full color flat panel displays. The group's work was the first successful demonstration with crystalline organics of full color technology which meets the requirements for "heads up" displays and those for very large scalability and light-weight flat panels. The schematic shows a cross-sectional diagram of a typical crystalline organic light emitting device based on the compound tris (8-hydroxyquiniline) aluminum (al).

crystalline organics of full color technology which meets these requirements and those for very large scalability and light weight flat panels.

In Professor Forrest's research, the thin films for the LED devices are deposited in a vacuum on glass using a novel technology known as "organic molecular beam deposition," developed under AFOSR sponsored research. The resulting structures are extremely thin (approximately 10-8m) and are nearly transparent when turned on. In the "on" state, light efficiencies of greater than one percent have been achieved, comparable to the highest efficiencies attained using conventional semiconductor LEDs.

Crystalline organic materials can be deposited on extremely large surfaces such as mylar sheets or window glass and have the potential for very high reliability. The many qualities and capabilities of crystalline organic materials provide a significant edge over the competing full color display technologies based on liquid crystals, polymers, or semiconductors. There is now an extensive world-wide effort being made to take advantage of crystalline organic materials for displays, much of it centered in Japan. Professor Forrest's work continues to keep the United States on the cutting edge in device and materials technology in this increasingly important and competitive area of organic thin films.

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New Laser Promises Advances in Optical Countermeasures

Dr. C.L. Tang and his research group at Cornell University have developed a high-intensity pulsed laser which can be tuned to emit in any color, from deep in the infrared through the visible spectrum to the near ultraviolet. The laser is capable of emitting infrared radiation of one to three microns in wavelengths, the region of the infrared spectrum which is of intense interest to the Air Force optical countermeasures electronic warfare community. Lasers of this type could be adapted for use in blinding or destroying the seekers in infrared seeking weapons and infrared surveillance systems.

The new laser produces one watt of output power at a 100 megahertz pulse repetition rate. The pulses themselves last only 100 femtoseconds (one femtosecond is a millionth of a billionth of a second), opening the door to the scientific investigation of extremely short-lived physical processes in metals and semiconductors. Industrial interest in commercializing these results is intense and Cornell has signed technology transfer agreements with Spectra Physics, one of the world's largest manufacturers of lasers.

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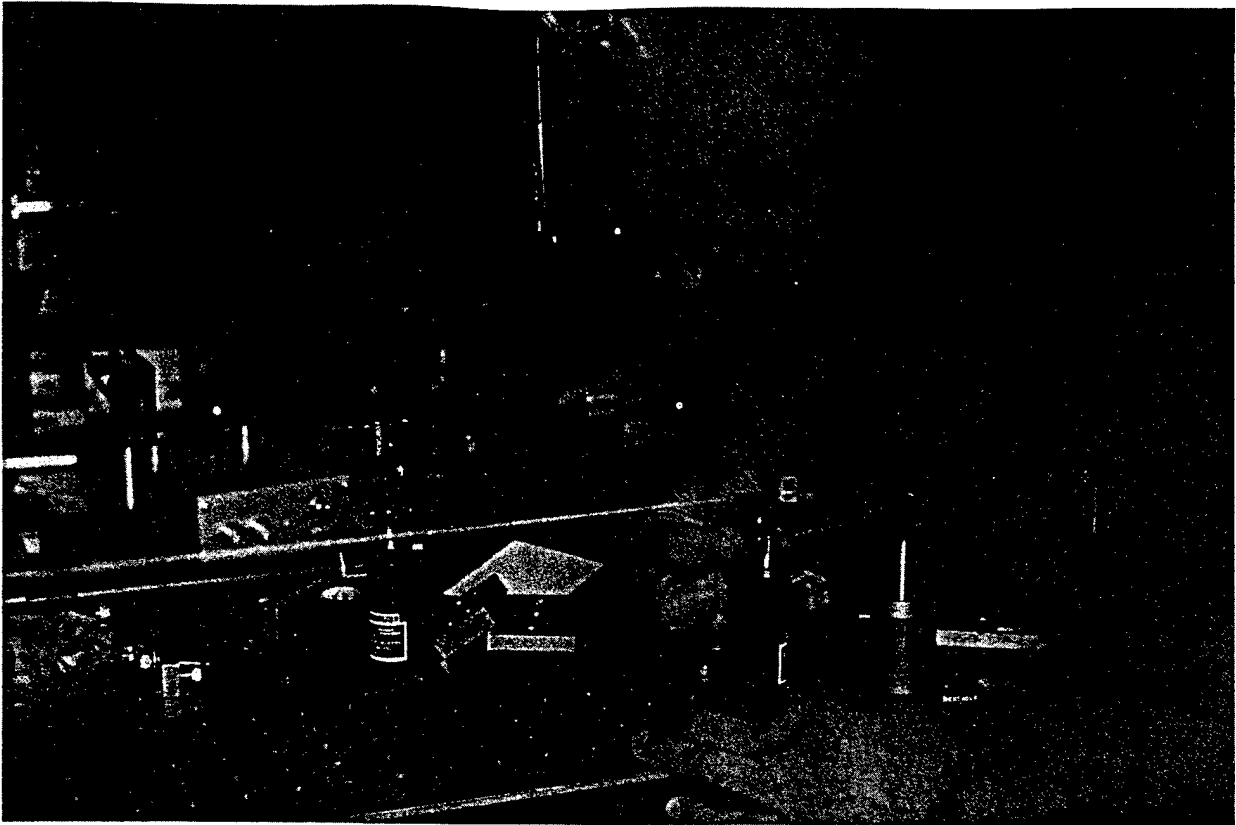


Figure 7. Dr. C.L. Tang and his research group at Cornell University have developed a laser which can emit in any color from the infrared through the near ultraviolet. It is capable of emitting infrared radiation of one to three microns in wavelengths, a region of the infrared spectrum of intense interest to the Air Force electronic warfare community. A Cornell University scientist is adjusting the frequency of the light emitted by this tunable femtosecond laser. Tuning is accomplished by the simple expedient of rotating the crystal as shown. (Accompanying text – page 16).

Microscopic Imaging Breakthrough to Enhance Air Force Electronics

Professor Aaron Lewis, who teaches and does research at Cornell University and the Hebrew University of Jerusalem, has pioneered a major advance in the development of an imaging technique termed Near-Field Scanning Optical Microscopy (NSOM). This technique is capable of forming optical images with unprecedented resolution. The resolution of an optical microscope is generally limited to a dimension roughly equal to the optical wavelength while NSOM resolution is approximately 50 times smaller. NSOM will allow major advances in the fabrication of higher density, smaller, and faster advanced microelectronic circuits. It will also allow the storage of high density information and permit the analysis of material failures at their most basic level. The new technique will enable the development of advanced Air Force electronic systems that are lighter, consume less power, take up less space, and have greater functionality.

The degree of resolution made possible by Professor Lewis' research is normally achieved only with electron beam imaging which requires extensive preparations including procedures which

can drastically alter the sample observed. In another application, NSOM can be used as a light source of tiny dimensions that could extend microelectronic optical lithographic techniques well beyond current resolution limits. NSOM tiny light sources also hold great promise for optical information storage by vastly increasing the storage density over existing techniques. This potential was recently demonstrated by Dr. Eric Betzig of AT&T Bell Laboratories. Dr. Betzig received support from AFOSR when he was a graduate student under Professor Lewis.

Professor Lewis developed NSOM by scanning a light source through a tiny aperture tip extremely close to a sample so that normal (far field) diffraction of the light did not occur. This approach was made possible by the scanning techniques developed in recent years for a variety of "tip" microscopies such as scanning tunneling microscopy (STM). However, until a recent Lewis breakthrough, it was very difficult to regulate the distance between the aperture and sample during scanning to prevent the tip from damaging the sample. Professor Lewis uses an independent feedback technique to regulate the aperture and sample separation. The feedback signal comes from a specially developed procedure that enables the aperture tip to be used simultaneously as an NSOM source and an STM probe. The tunneling current of the tip provides the feedback signal that enables it to maintain a constant distance from the sample during scanning.

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Major Improvement Made in Semiconductor Structures

A team from the University of Illinois headed by Professor Hadis Morkoc has fabricated gallium arsenide (GaAs) semiconductor structures with significantly improved interface quality. Electronic devices incorporating these structures will enable the production of integrated circuits rivaling those made from silicon in their levels of complexity while offering the speed and power consumption advantages of compound semiconductors. These qualities, coupled with the superior radiation tolerance of GaAs circuits, are ideally suited to the production of Air Force electronic systems with advanced performance and reduced power requirements.

One of the principal reasons for the continuing predominance of silicon-based semiconductor integrated circuits is the unique nature of the silicon-oxide and silicon-nitride interfaces. These technologically important interfaces are notable for their stability and a very low density of defect states. Both qualities are critical for successful electronic applications. In contrast, the normal GaAs oxide structure is unstable and has interface defects 10 to 100 times that of silicon.

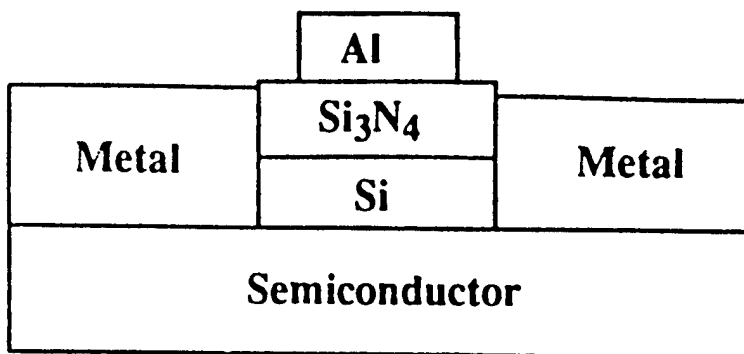


Figure 8. University of Illinois scientists have fabricated gallium arsenide (GaAs) semiconductor structures with significantly improved interface quality. The normal GaAs oxide structure was unstable and had interface defects many times that of silicon-based semiconductors currently used in Air Force electronic systems. The University of Illinois team was able to overcome the drawbacks of GaAs native oxides by incorporating a GaAs-silicon-silicon nitride composite (shown in the figure) in their place.

The University of Illinois team was able to overcome the drawbacks of the GaAs native oxides by incorporating a GaAs-silicon-silicon nitride composite in their place. In this work, they found that the addition of hydrogen during the *in situ* growth of a very thin silicon overlayer followed by a silicon nitride cover layer leads to a GaAs interface of silicon quality.

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New Instruments and Techniques for Nondestructive Inspection Developed

A Vanderbilt University research team led by Dr. John P. Wikswo, A.B. Learned Professor of Living State Physics, has developed a number of novel instruments, measurement techniques and analytical methods for the nondestructive inspection of aircraft and the detection of deep-lying structural defects. This work holds great promise for the Air Force in dealing with its aging fleet of aircraft. The key component in the new techniques is a superconducting magnetic sensor known as a superconducting quantum interference device (SQUID) which has unparalleled sensitivity to small changes in a magnetic field, a feature that provides the basis for a new generation of eddy-current detectors.

The research at Vanderbilt was conducted under an AFOSR grant titled High Resolution SQUID Magnetometry for Nondestructive Evaluation. The experimental and theoretical studies demonstrated that extremely low frequency eddy current (ELF EC) measurements using SQUID's operating between 1 Hz and 100 Hz are capable of detecting flaws in aluminum at a depth of five millimeters or more. The use of a large conducting sheet as a current inducer provides sufficiently uniform currents to allow quantitative determination of flaw size. Also, current can be injected

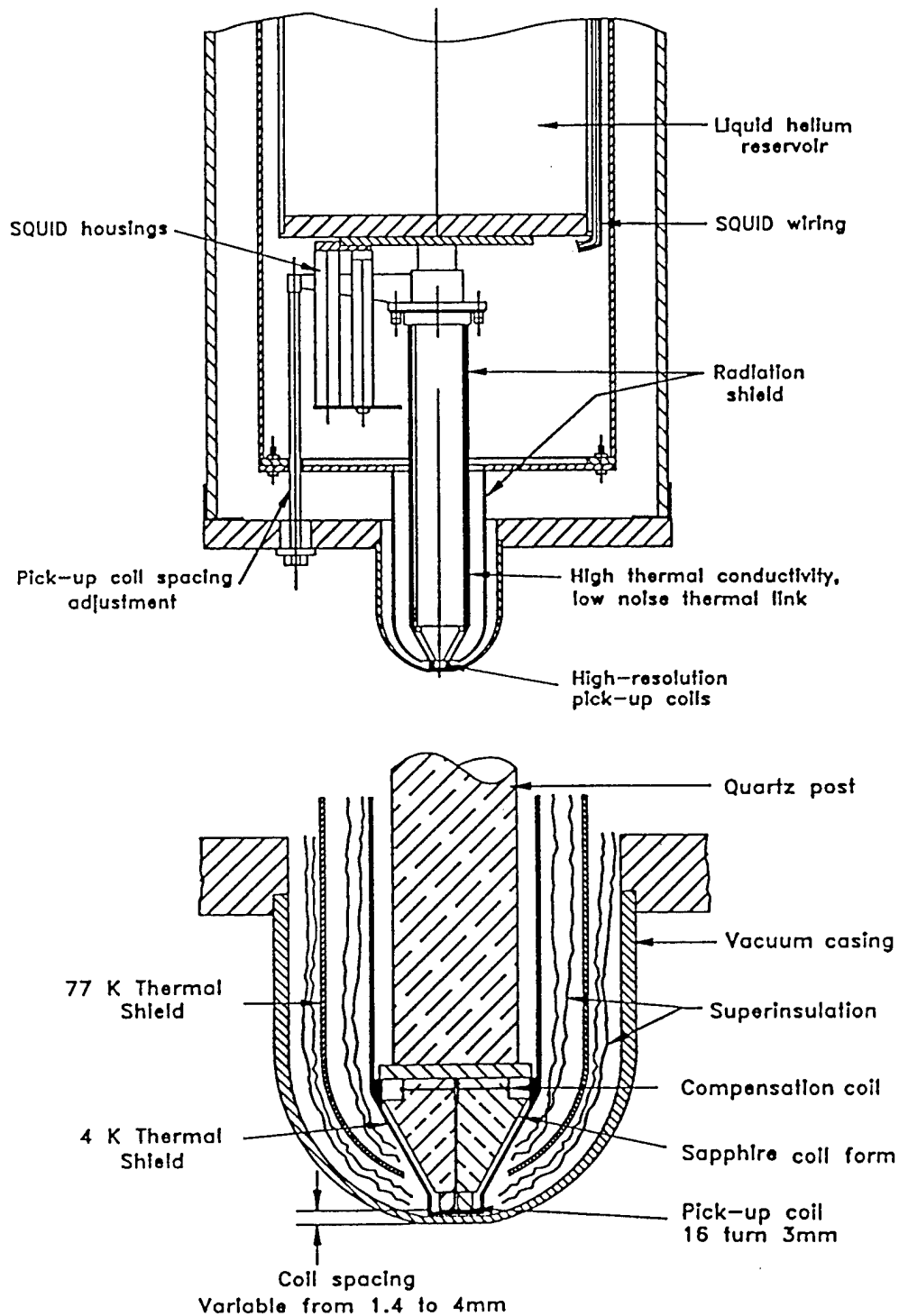


Figure 9. Research at Vanderbilt University has discovered a number of novel measurement techniques, analytical methods, and instruments for the nondestructive inspection of aircraft. The key component in the new techniques is the superconducting magnetic sensor known as the SQUID depicted here. The SQUID has unparalleled sensitivity to small changes in a magnetic field, a feature that makes it invaluable in the nondestructive inspection of aging aircraft.

directly into the sample and techniques developed at Vanderbilt greatly reduce the magnetic field that is normally associated with the current leads. Normally, the current leads would give rise to additional magnetic field components that could mask the magnetic field anomalies associated with structural defects.

The results of the Vanderbilt research can be readily incorporated into simple, portable, high-transition-temperature SQUID magnetometers cooled with liquid nitrogen. They will be capable of finding specific aircraft flaws that would be difficult or impossible to detect with conventional nondestructive evaluation techniques. Special pickup coil designs and SQUID-based noise cancellation techniques will make it possible to take measurements in magnetically noisy air logistics center maintenance hangars.

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Power Source Provided for ARPA, Industrial Radar, Communications Programs

A research team led by Professor Neville Luhmann at the University of California (Davis) is providing the key enabling technology for a multimillion dollar Advanced Research Projects Agency (ARPA) program to develop a 95 GHz Fast-Wave Amplifier. The amplifier will serve as a source of high-frequency microwave power to drive the next generation of radar and communications systems for the Air Force and the other services.

Varian, Litton, Northrop and the Naval Research Laboratory are currently receiving funds from ARPA to develop the amplifier. However, before any of the studies could begin, each research group needed a method for generating an axis-encircling electron beam to drive the proposed devices. The only available method was Professor Luhmann's Gyroresonant Radiofrequency Accelerator which he developed under an AFOSR grant. Luhmann graciously agreed to make his accelerator available to all four groups until they develop alternate beam sources.

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New Type of Memory Circuits Offer Vast Improvements in Computers

A team of scientists under the direction of Professor Konstantin Likharev at the State University of New York at Stony Brook has designed and tested a new family of ultrafast, superconductive logic

and memory circuits. The vast improvement in speed and corresponding reduction by four orders of magnitude in heat evolution of the new circuits have important implications for the future generations of digital signal processors and superconductors needed for military and commercial applications. This discovery will enable the Air Force to carry out real-time signal processing in aerospace systems.

The circuits, known as the Rapid Single Flux Quantum (RSFQ) logic family, are based on a type of bit in which neither the zero nor one state dissipates any energy. The nature of the state is determined solely by the absence or presence of a single quantum of magnetic flux. In the first experimental application of RSFQ, the Stony Brook group produced a single-bit full adder circuit which was more than 100 times faster than a comparable silicon-based circuit. With reduction to the dimensions used for silicon, the RSFQ circuit would actually be 500 times faster.

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Directorate of Life and Environmental Sciences

More Accurate Radar Wind Profiling System Developed

Dr. Miguel Larsen of Clemson University has developed the first accurate radar wind profiling system for measuring atmospheric vertical motions. Air Force weathermen will be able to make more accurate forecasts with the improved profilers and researchers can use them to study atmospheric fluid dynamics.

Measurements taken from current profilers without his new technique are subject to errors in excess of 100 percent. The impact of Dr. Larsen's discovery could be far-reaching since the United States Weather Service is currently installing a new network of 30 wind profilers. None of these are configured with Larsen's modification and the accuracy of their vertical velocity measurements must be viewed with considerable doubt. Adding his improved technique to these profilers would be relatively inexpensive and would dramatically increase their accuracy.

Dr. Larsen made his discovery while working with prototype profilers in Germany and Japan where scientists could not explain the discrepancies between the vertical motions they observed and the general weather conditions. He discovered that if he converted the profilers electronically into "interferometers," the discrepancies disappeared. He also determined that the source of the errors was an occasional slight tilt in the atmosphere's refractive layer used as a target by the profilers. He calculated that tilts of less than one degree could cause measurement errors as large as 200 percent.

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Research Suggests Method to Eliminate Pitch Illusion in Night Flight

Recent research by Professor Leonard Matin of Columbia University provided new insight into improving flight safety at night. His research suggests that two vertical lines projected on the windscreen of a cockpit via a small Heads-Up-Display would eliminate or reduce the illusions in pitch attitude that occur in night flight. These illusions are caused by sensory conflicts between body position and motion due to the visual and vestibular sensory systems. The impact of Professor Matin's discovery could greatly increase flight safety for commercial and military aircraft flying at night.

Professor Matin conducted a sequential set of experiments that examined the effects of vision alone and vision plus vestibular involvement in determining visually perceived eye level (VPEL),

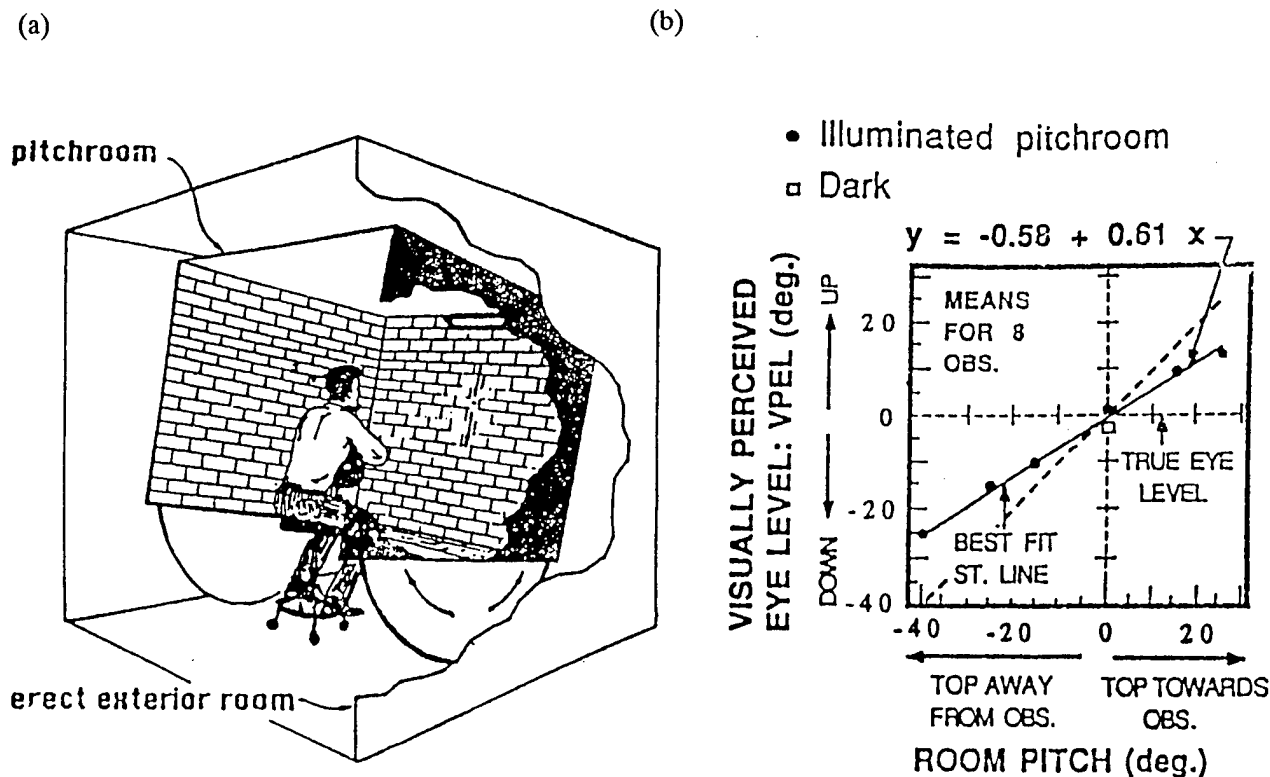


Figure 10. Columbia University research suggests a way to reduce illusions in pitch altitude in night flight. A series of experiments examined visual and vestibular involvement in determining visually perceived eye level (VPEL). The work revealed that the illusory pitch sensations at various G-loads could last for several minutes but were reduced or eliminated when vertical lines were introduced into the visual flight field. Figure 10(a) shows the VPEL effect at 1 G created by using a tilt room. The illusion will be tested in a specially configured centrifuge to investigate illusory effects at higher G levels. 10(b) shows the difference between perceived and actual eye level at 1 G.

the equivalent of straight and level flight. The model Professor Matin developed showed that visual field and body reference mechanisms (e.g., G-forces and vestibular system) act linearly and independently. His research revealed that the influence of visual pitch angles from environmental cues (e.g. mountainous terrain and cloud formations) on VPEL is extensive and long lasting. He demonstrated that when an environmental cue is visible at night at an angle of 40 degrees (top away from the pilot), the average VPEL was 25 degrees below true eye level. This illusory sensation from the visual cues could result in an inappropriate control input such as pushing the nose of the plane down 25 degrees to maintain level flight. Conversely, when terrain is at an angle pitched 25 degrees toward the pilot, VPEL is set at 15 degrees above true eye level, indicating that a climb is the desired response to maintain straight and level flight.

Professor Matin further explored the VPEL illusion by varying G loads between 1.0 and 1.5Gz to simulate the flight environment of aircraft flying at night with the same results. The illusory pitch sensations at the varying loads could last for several minutes, but were greatly reduced or eliminated when two vertical lines were introduced into the visual flight field. Additional research

to explore these effects up to four Gz will be conducted by Professor Martin and Dr. William Alberry at Wright-Patterson AFB in August.

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Life Sciences Research Improves Pilot Performance

Drs. Richard Wurtman and Andy Dollins of the Massachusetts Institute of Technology and Dr. John French of the Air Force's Armstrong Laboratory tested the effects of L-Tyrosine (a dietary amino acid) on pilots exposed to the fatigue and stress of an eight-hour simulated mission. The scientists evaluated 14 instrument-rated pilots in two 27-test sessions to measure their ability to remain within Air Force criteria for airspeed, bank, heading, and vertical velocity during repetitions of 14 different flight maneuvers. They observed that flight performance error was lower when the subjects were taking L-Tyrosine instead of a placebo on 52 of the 66 flight measures. Since L-Tyrosine occurs naturally in proteins, a diet high in proteins and low in carbohydrates would help aircrews remain more alert on long missions.

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Study of Jet Fuels Toxicity to Improve Environmental Risk Assessment

In a study on the environmental impact of jet fuels, Drs. Wayne Landis, Robin Matthews and Geoffrey Matthews of Western Washington University developed new methods of analysis that have led to fresh insights into the way an ecosystem responds to chemicals. Their insights may contribute significantly to improving the science that environmental risk assessments are currently based on and greatly reduce the costs of cleaning up hazardous waste sites. The billion-dollar environmental cleanup costs facing the Air Force, DOD and the nation are determined, to a significant extent, by a process of risk assessment that tries to predict the environmentally safe concentrations of toxicants. A process that provides more accurate risk assessments could save the Air Force millions of dollars.

Due to lack of scientific information, conservative assumptions of risk or uncertainty factors are inserted into the environmental risk assessment process. This usually results in the setting of unrealistically low concentrations as the accepted safety levels, thereby increasing the difficulty and cost of environmental cleanup. The methods and results derived from this research on jet fuels

can lead to more realistic and lower cleanup costs. The researchers used an innovative analysis approach and methods derived from artificial intelligence and employed a new three-dimensional visualization technique referred to as "wormspace" to record jet fuel-induced alterations in an ecosystem. Their research indicated that there was an intrinsically chaotic behavior to the population interactions of an ecosystem. The implication of this discovery will be to set greater limits on the predictability of ecosystem dynamics and call into question the accuracy of predicting environmental risks from low levels of toxic chemicals. Setting prediction limits will tend to reduce the inherently conservative approach to risk assessment and, most likely, the enormous cost of environmental cleanup.

Professors Matthews, Landis and Matthews were recently invited to present their findings to the Environmental Protection Agency's Regional Risk Assessment Annual Meeting in Atlanta, Georgia on 4 May 1993. Their statistical and analytical methods will be packaged into a software program called RIFFLE and made available to users for a nominal fee.

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Improved Forecasting of Solar Phenomena to Protect Space Systems

Dr. David Webb of the Institute for Space Research at Boston College and Professor Bernard Jackson of the Center for Astrophysics and Space Sciences at the University of California, San Diego have identified the characteristics of solar coronal mass ejections (CMEs). This research offers the possibility of forecasting the occurrence of solar mass ejections in the near-earth environment. The ability to timely forecast impending geomagnetic disturbances will enable Air Force space system managers to take the necessary action to minimize the impact on their ground communications, navigation systems and satellite operations.

Massive releases of solar radiation in the form of ionized particles travel rapidly to earth and can disrupt Air Force communication and navigation systems. This radiation also causes problems for military satellite operations and is potentially lethal for manned space flights, especially those in polar orbit where the earth's magnetic field does not operate as a shield from ionized particles.

Professors Webb and Jackson used white light photometer data from the Helios spacecraft to describe the characteristics of solar CMEs observed in the interplanetary medium. The results of their research based on this data suggested that typical heliospheric CMEs have large dimensions, supply significant amounts of mass to the inner heliosphere, and are associated with major changes in the interplanetary magnetic field. Their data provided the first good information about heliospheric masses and the shapes of disturbances propagating through space from the sun. The imaging of heliospheric plasmas by the spacecraft, combined with other observations, provided a

unique opportunity to determine CME velocities, solar streamer material velocities, and their three-dimensional heliospherical shape.

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Research to Increase Computer Screen Reading Rate

Professor Bruce Bridgeman of the University of California at Santa Cruz has shown that increasing the refresh (scan) rate of cathode ray tube (CRT) screens could increase productivity in the Air Force and the civilian sector. Bridgeman has demonstrated that increasing the scan rate greatly reduces fatigue and prevents the productivity curve from dropping off sharply after operators have used their screens for a few hours. Given the millions of hours military and civilian personnel spend reading from terminals, researchers estimate the productivity increase could be worth billions. The results of this dual-use research are also important to civil and military aviators because of the increased use of CRTs in cockpits to display primary flight information. Aviation safety would be improved since pilots could react more quickly to the information on CRT displays and they would experience less fatigue, one of the major causes of accidents.

Bridgeman compared the performance of personnel using the normal 60 hertz (Hz) CRT screen with those using a more advanced 500 Hz screen which displays information more rapidly. The advantages of a 500 Hz CRT scan included increased reading rates and no reported fatigue or eye strain. These improvements can also be obtained with the more technologically feasible scan rate of 120 Hz.

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New Software Allows Efficient Optical Character Recognition

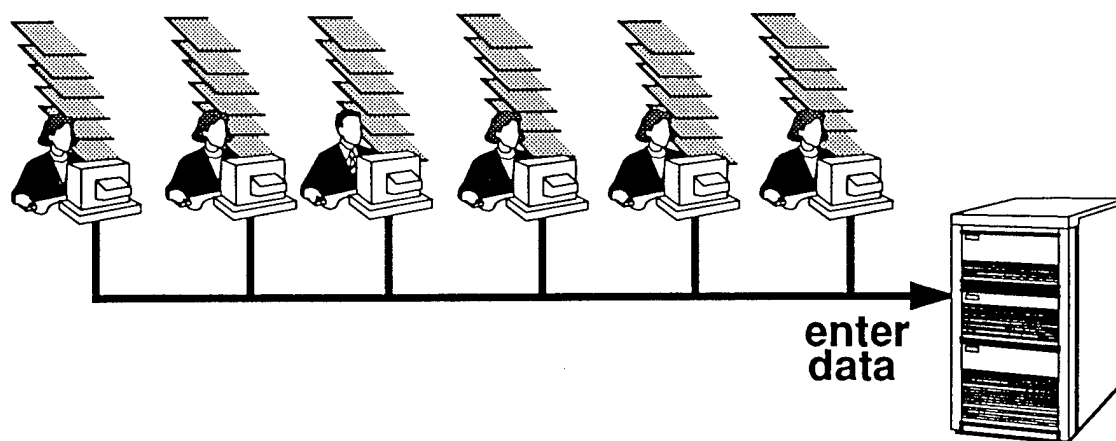
Dr. Michael Kuperstein of Symbus Technology Inc., Waltham, Mass., has developed image processing software for reading handwritten text and numbers. Use of this software in major systems to process forms has resulted in labor savings up to 85 percent. Systems based on this software promise similar savings for the Air Force in situations where operators currently have to manually retype the text and numbers from handwritten forms.

A neural network based on human learning of visuomotor coordination forms the basis for this software. In human visuomotor control, visual coordinates of an object are linked to specifications

of movements to reach that object. In optical character recognition, stroke patterns used to produce a character are linked to the set of character categories. In the solutions to some optical character recognition problems, associative maps or look-up tables are constructed to form the link. Dr. Kuperstein's research sought to determine how associative maps could be learned by neural networks which were free to generate their own movements to explore novel environments. In this approach many mistakes are made at first but if the neural network is carefully managed, the resulting system can be much more flexible than those which must be told the minute details of every environment. Kuperstein adapted the neural network he built to study visual-motor links to the task of optical character recognition.

Dr. John Tangney
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a. The Need: Labor costs for keying data is very high



b. The Solution: Automatic data entry to minimize labor costs

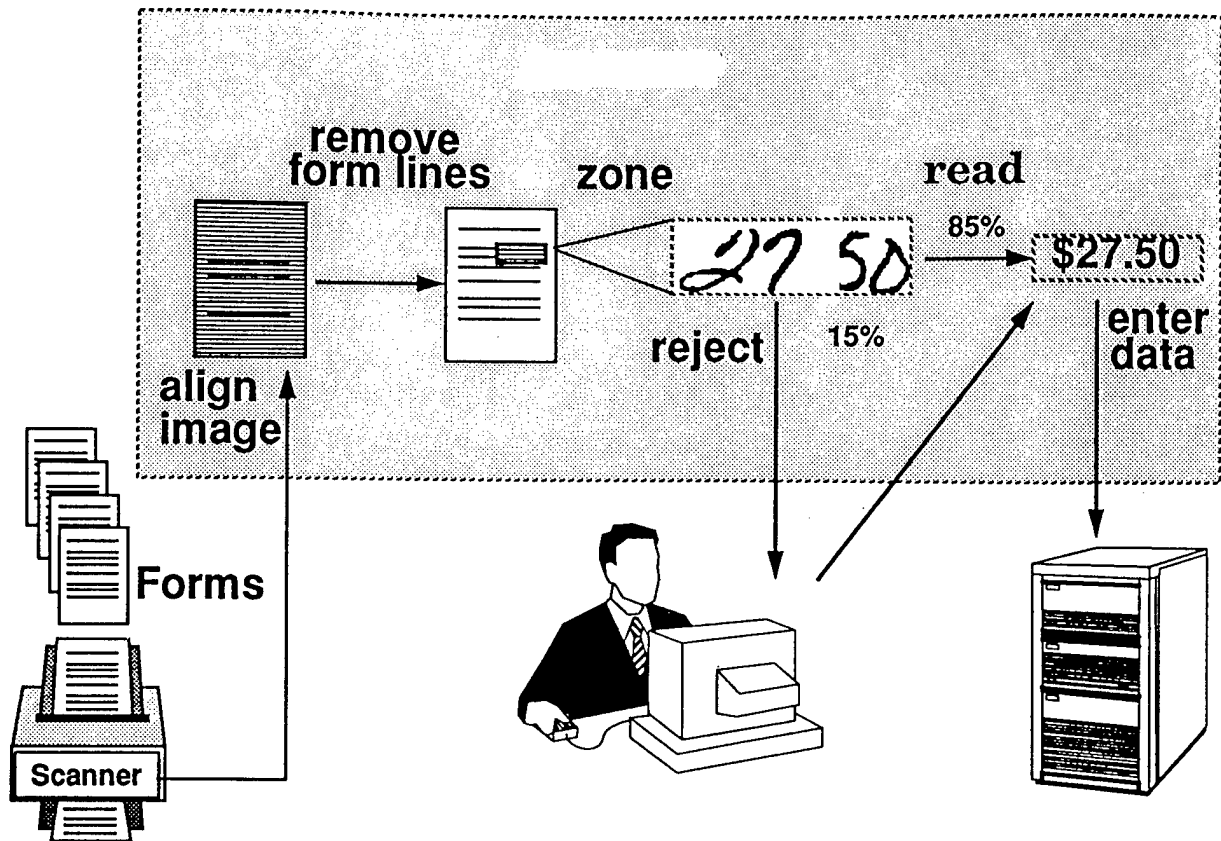


Figure 11. A new software to process forms, based on the human learning of visuomotor coordination, has created a labor savings of up to 85 percent. Copying data from written forms is extremely labor intensive (a), but labor can be greatly reduced by using new systems that process entire forms and recognize the numbers entered (b).

Trainable Robot Arm Built from Biologically-Based Learning Control Algorithms

Martin Marietta Aero & Naval Systems has successfully applied drive-reinforcement learning algorithms to the control of a two-degree-of-freedom robot arm (Figure 12). Dr. Harry Klopff and his basic research team at Wright Laboratory developed the algorithms as part of a project in biologically-based machine intelligence. The Air Force logistics community can use this method to move heavy or dangerous equipment.

The algorithms engage in real-time, closed-loop, goal-seeking interactions with the environment, and are capable of learned responses consistent with that observed in animals and humans such as learning to connect a series of responses that avoid punishment and eventually lead to a reward. Movement of the robotic arm is smooth because the arm joints are moved in parallel rather than in

series. More importantly, the controller learns the task quickly and autonomously on-line, while conventional means of control require considerable prior engineering design. Martin Marietta will deploy this controller on a field materiel-handling robot developed for the Army. The robot will function as a forklift to off-load pallets of ammunition from trucks. The Department of Energy is interested in using the robot to move toxic and nuclear waste.

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Program Manager for Chronobiology
202-767-502, DSN 297-5021

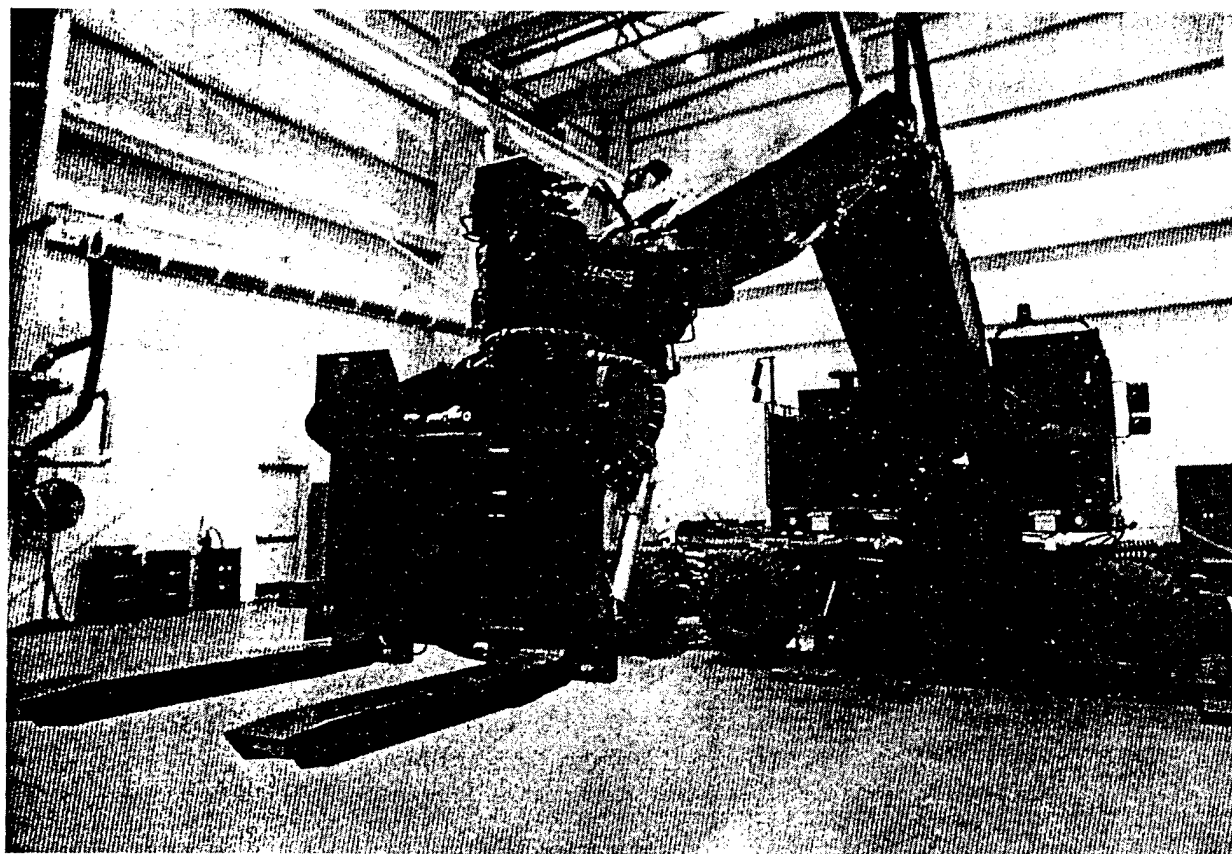


Figure 12. A Wright Laboratory basic research team developed drive reinforcement algorithms as part of a project in biologically-based machine intelligence. Martin Marietta Aero & Naval Systems successfully applied these algorithms to the control of the two-degree-of-freedom arm on the six-degree-of-freedom field material handling robot pictured here. The robot was designed to handle pallets of ammunition and hazardous wastes.

Directorate of Mathematical and Computer Science

Math Research Breakthrough Enhances Manufacture of Computer Chips

Professor Eytan Barouch of Clarkson University and Professor Steven Orszag of Princeton University have solved a major High Performance Computing and Communications (HPCC) Grand Challenge Problem. This breakthrough makes it possible to use simulation as an effective tool in the design of microchip manufacturing processes. This translates into cheaper, more reliable chips for a wide variety of Air Force systems.

Potential applications for simulation in microchip design include illuminator optimization and mask designs. This accomplishment dramatically improves the ability to make quantitative predictions and reduce the large number of empirical and experimental mask designs previously required in microchip development. Barouch and Orszag's work builds upon AFOSR-sponsored

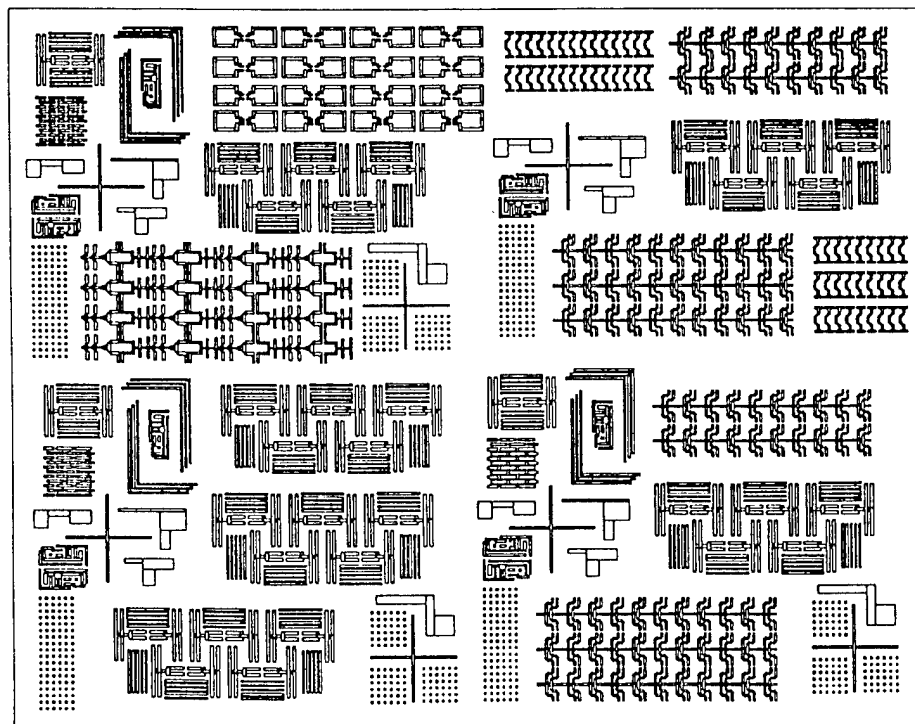


Figure 13. A breakthrough by researchers at Clarkson and Princeton Universities makes it possible to use simulation as an effective tool in the design of microchips. This will allow the production of cheaper, more reliable chips for Air Force systems. Before their breakthrough, researchers were only able to simulate 20 x 20 micron chips. The university researchers simulated a full-scale aerial image of a 1250 x 1275 micron I-line mask. Shown here is an IBM test case of a 120 x 150 micron mask using I-line illumination. The computation of this test case takes less than an hour. Previous algorithms would have required more than two years of CPU time on a comparable workstation.

research in nonlinear optics which began at Clarkson University in the early 1980s as well as research on the development of highly accurate spectral-based methods for numerical simulations. Copies of this software are available without charge for official U.S. Government use.

Professors Barouch and Orszag have for the first time computed a full-scale aerial image of a genuine 1250×1275 micron I-line mask. Until now researchers have only been able to simulate portions of chips not exceeding 20×20 microns. This work was performed under both AFOSR and ARPA sponsorship including contracts to Clarkson and Princeton for mathematical modeling and computational simulation. The mathematically rigorous and physically accurate models were implemented using a newly developed, non-uniform grid "Fast Fourier Transform" with minimized memory requirements. The first computation with this particular example took under 24 hours. Eventually, researchers expect to further reduce the computational time by an order of magnitude which will make possible the full-scale, accurate simulation of an entire chip.

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Modeling of Shock Waves for Enhanced Combustor Efficiency

Until now, high order numerical methods capable of rapidly resolving the fine details of complicated, smooth, aerodynamic flows have not been useful when the flows are not smooth, as in the case of shock waves. Scientists have understood for some time that the reason for this is the decreased convergence rate and the spurious oscillations caused by the so-called Gibbs phenomenon, discovered in 1898 by the famous physicist, Albert Michelson. The mathematical cause of this phenomenon was explained in 1899 by J. Willard Gibbs. For nearly a century mathematicians and computational scientists have been trying to find effective ways to finesse this apparent barrier to use high order approximation methods for the numerical simulation of physical phenomena which have shocks.

Recently, Professor David Gottlieb and his co-workers at Brown University, working under AFOSR sponsorship, have resolved this 100 year old mathematical problem! They developed a highly efficient filtering algorithm which can be coupled with high order spectral methods in a post processing phase to obtain high order accuracy in the numerical simulation of non-smooth flows with negligible additional computational burden. This work is expected to have widespread applications in Air Force aerodynamic design problems such as enhanced mixing in combustors.

Professor Gottlieb's team and Dr. Abdi Nejad of the Air Force Wright Laboratory are now engaged in numerical studies aimed at understanding the best way to enhance mixing in the combustor of a SCRAMJET by creating a vortical motion through interactions of shock waves and hydrogen jets. Professor Gottlieb's discovery also has stirred great interest in the scientific

community, and he has been invited to present this research in a plenary address to the 1993 Annual Meeting of the Society of Industrial and Applied Mathematics.

Dr. Marc Jacobs
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New Optimization Techniques Improve Manufacturing, Aerospace Design

Professor John Dennis and his colleagues at Rice University have developed novel techniques that provide dramatic improvement in the solution of large scale global optimization problems. These problems occur in a variety of scientific and engineering application areas which affect the Air Force ranging from manufacturing to aerospace design. Recently, one technique was successfully applied to the manufacturing problem of minimizing trim loss associated with cutting metal stock from rectangular sheets. Boeing Aircraft Corporation claims to have reduced its trim loss by ten percent through use of this superior optimization technique.

Professor Dennis is now applying his techniques to critical "multidisciplinary" problems that are mathematically-modeled systems of partial differential equations. His goal is to design an airfoil that maximizes a measure of performance such as lift-to-drag ratio, subject to appropriate constraints on the aerodynamic loads and structural deformations.

Before Professor Dennis developed his techniques, solutions to these high-dimensional problems could not be obtained using reasonable computation resources. In his novel approach, the physical object or domain being studied is subdivided into smaller subdomains, new variables and constraints are introduced to force consistency among these units, and the optimization is performed on each of the smaller and less complex subdomains separately. In addition to reducing the complexity of the computation, this approach offers the possibility of speeding up the calculation through parallel processing. Boeing Aircraft is currently investigating the feasibility of this approach to aircraft design.

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New Algorithms Improve Air Force Scheduling and Logistics Systems

Professor Matthew Ginsberg of the University of Oregon has developed a broad new class of search algorithms which are much more effective than existing methods for constraint-satisfaction problems. Because of the close relationship between constraint-satisfaction and scheduling, a variety of Air Force systems can benefit from this breakthrough. For example, almost all transportation planning problems, the optimal allocation of repair and maintenance equipment and the scheduling of operational missions are amenable to Ginsberg's technique.

The existing methods for solving these problems treat the space of possible solutions as a tree, gradually adding new decisions and retracting them in order when a problem is discovered. Ginsberg found a method to treat such spaces as graphs with a high degree of connectivity, allowing solutions to be found more quickly. This technique is known as a "lateral" search because the transitions allowed by the graph span large distances when viewed as motion in the original search tree. The key technical innovation in Ginsberg's work involves managing information about the portions of the search space already examined. Previous researchers were unable to deal with this problem because they assumed an exponential amount of memory was needed to record the necessary information. Professor Ginsberg has shown that a much smaller, polynomial amount of information is sufficient.

Dr. Abraham Waksman
Program Manager for Artificial Intelligence
(202) 767-5028, DSN 297-5028

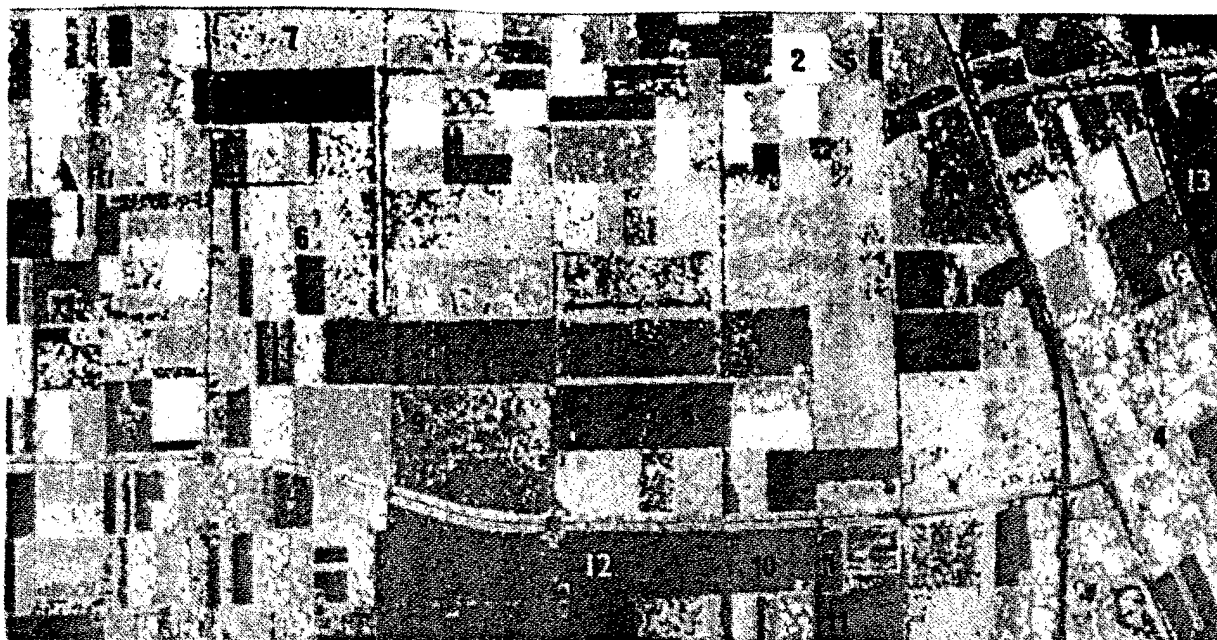
Breakthrough Achieved in Synthetic Aperture Radar Technology

Professor Rama Chellappa of the University of Maryland, College Park, has combined a strong theoretical technique with an ability to work field data to improve image understanding in Synthetic Aperture Radar (SAR). SAR plays a prominent role among the sensing technologies employed by the Air Force for reconnaissance and tracking. Professor Chellappa's discovery will make SAR even more effective at identifying features of interest in terrain under observation.

Researchers have long studied a variety of image processing methodologies in the visible range including edge detection, deconvolution, shape from shading, and segmentation. However, the SAR image generation process involves different physics and a new approach to image understanding problems. Professor Chellappa's breakthrough involves segmentation mapping where

POLARIMETRIC CHARACTERISTICS OF THE CLUSTER CENTERS. FLEVOLAND SCENE—L-BAND

Cluster	σ_{HH} (dB)	σ_{HV} (dB)	σ_{VV} (dB)	$\sigma_{ HHVV ^{1/2}}$ (dB)	ϕ_{HHVV} (rad)	Nature
1	-2.6	-19.4	-9.1	-8.6	2.08	Man made targets
2	-9.9	-16.9	-10.2	-13.0	0.13	Forest + Potatoes
3	-10.3	-20.2	-11.8	-18.0	1.63	Stem Beans
4	-11.3	-17.3	-11.5	-17.0	0.13	Forest
5	-12.8	-21.5	-11.9	-14.5	-0.19	Red Beet + Peas + Beet
6	-14.0	-21.4	-14.2	-19.0	-0.09	Beet
7	-15.2	-25.1	-13.0	-15.8	-0.28	Bare Soil
8	-16.5	-25.8	-17.3	-24.5	-0.45	Lucerne
9	-17.2	-26.7	-15.6	-19.0	-0.40	Winter Heat + Grass
10	-17.8	-28.7	-18.4	-28.2	1.21	N.A.
11	-19.4	-29.0	-20.6	-28.6	-2.32	N.A.
12	-20.1	-29.3	-18.6	-22.2	-0.43	Grass + Summer Barley
13	-22.2	-35.8	-17.5	-20.6	-0.17	Flax + Water



(a)

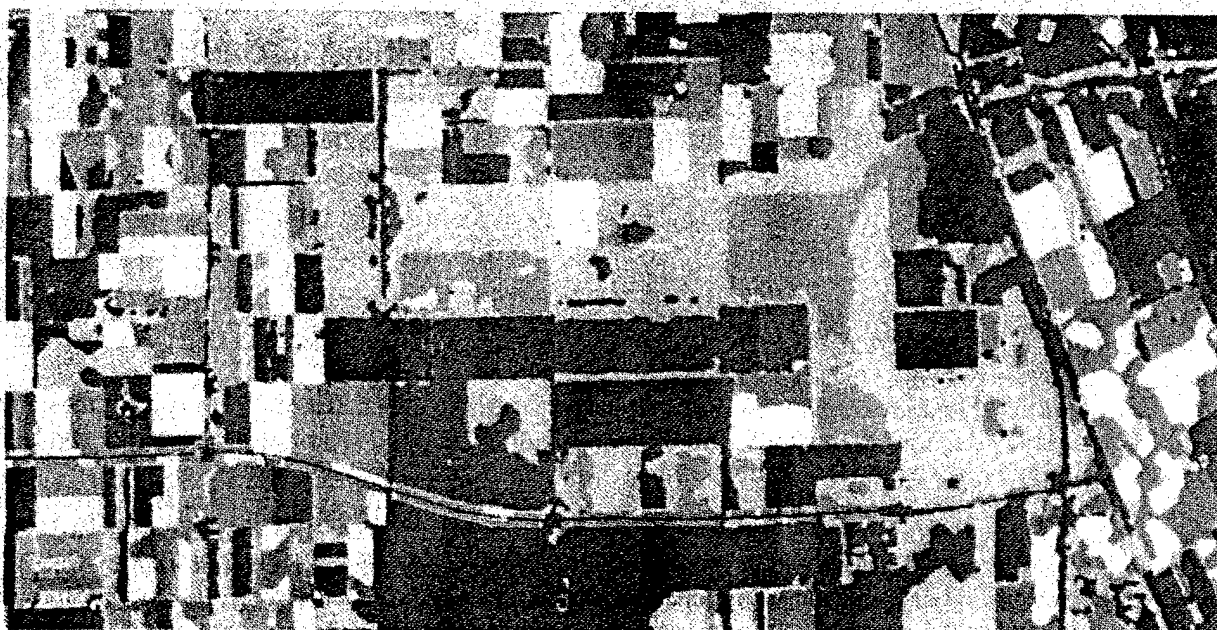


Figure 14. Improved image understanding in Synthetic Aperture Radar (SAR) is now possible thanks to work by a University of Maryland researcher. The breakthrough involves segmentation mapping where regions with similar characteristics are identified. Automated segmentation in SAR is illustrated in this scene involving various types of vegetation. Fully polarimetric SAR is employed in an unsupervised mode where the numbered "clusters" correspond to a particular crop as given in the table. (Opposite page).

regions with similar characteristics are identified. For example, sea, land and glaciers are separated or "segmented" in SAR imaging. This segmentation is more difficult to accomplish than with sensors employing natural light due to the type of coordinate projection which SAR uses and the backscatter "speckle" generated by its physical mechanism. Effective and automatic segmen-

tation makes possible rapid feature recognition and terrain estimation (topographical relief). It also allows the use of polarized radar emission and resulting classification of returns.

Professor Chellappa collaborated with Edmund G. Zelnio of Wright Laboratory's Target Recognition Technology Branch to accomplish his major work in the area of the segmentation of polarimetric SAR imaging. Real data for testing Chellappa's methodology is now available from Lincoln Laboratory, also the focal point of a DOD Automatic Target Recognition initiative in which SAR plays a significant role. Professor Chellappa capped a successful year of work in 1992 when his description of segmentation in SAR imaging, "A Computational Vision Approach to Image Registration" (with Q. Zheng), received the Best Industry Related Paper Award from the International Association for Pattern Recognition.

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New Method Solves Planning Problems Under Conditions of Uncertainty

Professor Judea Pearl of the University of California at Los Angeles has developed a qualitative-probabilities method which promises dramatic improvement in the solutions of planning problems under conditions of uncertainty. These problems occur in a variety of critical Air Force planning and scheduling tasks involving incomplete and changing information such as logistics deployment plans which have to accommodate changes in troop movements, different materiel requirements, and changing weather conditions. Pearl's method can be used to solve such problems.

Solutions to planning problems under uncertain conditions are difficult. In reasoning with standard logic it is not possible to retract beliefs in response to new observations and in traditional probability it is impossible to reason qualitatively using linguistic inputs. Professor Pearl's new method (Causal-Networks) combines logic and probability for the first time, benefiting from both. It is based on order-of-magnitude approximations of probabilities and utilities, and ranks actions by the expected utility of their consequences. With the aid of Pearl's method it is now possible to automatically derive natural priorities among conflicting rules (beliefs) and goals.

A very important aspect of the new method is the economy and simplicity of the knowledge required to describe how rules (beliefs) should change with actions and observations. A single Causal-Network residing in a system's knowledge base is sufficient for specifying behavior. It facilitates the analysis of actions, and as a consequence, the synthesis of plans and strategies under uncertain conditions.

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Small Business Grant to Improve European Airlift Scheduling

Dr. Ken Nygard of Netrologic Inc., working under an AFOSR small business incentive grant, is developing a new scheduling system for USAFE operational support airlift. This system will replace one that is manpower intensive and provides no means to increase scheduling efficiency. The new system will save considerable time and manpower requirements by producing effective theater airlift schedules more quickly. System installation and training will start in January 1994 with plans for the new system to be fully operational in six months.

European operational support airlift is a joint service command and control activity managed by USAFE. Since available airlift resources frequently support the White House or the Joint Chiefs of Staff, missions are often flown on short notice and require a complete rework of theater airlift schedules. Dr. Nygard's system is designed to improve accounting of unscheduled requests. His system combines both sophisticated mathematical and artificial intelligence components and an advanced human interface. An optimization algorithm, designed to provide the best service to previously unscheduled requests with minimum disruption for those already scheduled, interacts with schedulers through a "toolkit." The toolkit provides access to several views of existing schedules through maps, a simulated greaseboard and a display of all necessary supporting data. In addition, the new system provides computer support to coordinate the activities of schedulers who previously worked independently. These tools are proving capable of producing nearly optimal schedules.

Dr. Neal Glassman

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Recognition of AFOSR Researchers

The many awards received by principal investigators in 1993 provided continued evidence of the quality of scientists and engineers working under AFOSR sponsorship. The honors noted here are only the latest in a series of prestigious awards that have been conferred on AFOSR researchers since the 1950s. AFOSR has supported more than 20 scientists in the past four decades who were awarded the Nobel prize.

Fracture Mechanics Expert Awarded Eringen Medal by Society of Engineering Science

Dr. Fazil Erdogan, Professor of Mechanical Engineering and Mechanics at Lehigh University, was awarded the Eringen Medal given annually by the Society of Engineering Science (SES) for significant career contributions to the field of engineering science. Dr. Erdogan was awarded the medal for his continued contributions to the field of solid mechanics.

Professor Erdogan's acceptance lecture focused on his current research sponsored by AFOSR in the fracture mechanics of functionally-graded materials. These highly promising new materials have properties that vary continuously in order to give a predetermined composition profile. Professor Erdogan is developing the required fracture mechanics methodology for dealing with these new systems, since they violate the fundamental assumption for most materials that mechanical properties are relatively constant with position. The development of functionally-graded materials has opened new avenues of materials design for materials scientists and mechanicians. Applications of this material include thermal barrier coatings in high-temperature engine and airframe structures.

The award was presented at the "MEET'N'93" held in June 1993 at the University of Virginia in Charlottesville and jointly sponsored by SES, the American Society of Mechanical Engineers, and the American Society of Civil Engineers. Professor Erdogan is working with researchers and engineers at the Air Force Wright Laboratory, the DOE Oak Ridge National Laboratory, and the Idaho National Engineering Laboratory in this effort.

Program Manager Elected Chair of IEEE Committee

Dr. Robert J. Barker, AFOSR's program manager for Plasma Physics, was recently elected chairman of the 1000-member Institute of Electrical and Electronics Engineers (IEEE) Plasma Science and Applications Committee for 1993. Election to this position by his peers in the international plasma science and engineering community brings considerable prestige and high

visibility to the Air Force. As chairman, Dr. Barker will be responsible for ensuring the highest standards of quality for the group's annual International Conference on Plasma Science held in Vancouver, Canada in June and for publication of its professional journal, the IEEE Transactions on Plasma Science.

A member of AFOSR's program management staff since 1984, Dr. Barker frequently gives invited lectures and regularly chairs technical sessions at international scientific conferences in the field of plasma physics and vacuum electronics research.

Researcher Receives Prestigious Professional Society Teaching Award

Dr. Enrique J. Lavernia, Associate Professor of Materials Science and Engineering at the University of California at Irvine, received the 1993 Bradley Stoughton Award for Young Teachers from the American Society for Metals and Materials. This award is given annually to an outstanding young scholar under the age of 35 who has "demonstrated a dedication and commitment to the teaching of materials science." This marks the fourth time in the last seven years that this prestigious award has been won by an AFOSR principal investigator.

Professor Lavernia is rapidly establishing an international reputation for his research on the processing of materials. His investigations of solidification processing of intermetallic matrix composites have been supported by AFOSR over the last five years. His research plays a major role in the development of processing techniques and their relationship to the resulting mechanical properties for a variety of aerospace structural materials. These materials have potential for high temperature applications such as advanced engines and as skins for hypersonic aerospace vehicles.

AFOSR Principal Investigator to Receive 1993 Wolf and Plyler Prizes

Professor Ahmed Zewail of the California Institute of Technology was selected to receive two prestigious awards in 1993 in Chemistry and Physics: The Wolf Foundation Prize in Chemistry and the American Physical Society's Earle K. Plyler Prize for Molecular Spectroscopy. Professor Zewail was honored for his work in pioneering the field of femtochemistry, chemistry on the femtosecond time scale. A femtosecond is a millionth of a billionth of a second (or 10^{-15} second), less than the time it takes for atoms in a molecule to undergo a single vibration. Under AFOSR sponsorship, Professor Zewail established his femtochemistry laboratory at CALTECH. His work has allowed the visualization of what occurs as chemical bonds are formed or broken. The Wolf Prize, presented by the President of Israel at the Knesset building in Jerusalem, has proven a good predictor of future Nobel Prize winners. Professor Zewail is a member of the National Academy of Sciences, has received many distinguished international awards, and is one of the world's most cited authors in chemistry.

University of California Professor Receives Teaching, Achievement Award

Amiya Mukherjee, Professor of Materials Science and Engineering at the University of California at Davis, has been awarded the 1993 Davis Prize for Teaching and Scholarly Achievement. The \$25,000 prize was established by the University of California Davis Foundation through gifts of the Davis Chancellor's Club, and is believed to be the largest monetary award of its kind in the United States. The honor was established "to recognize and to encourage the ideal blend of scholarship and mentorship."

As University of California at Davis Chancellor Theodore Hullar said, "Amiya Mukherjee is an extraordinarily gifted and dedicated teacher and a distinguished scholar who shows us so well how fully our faculty members can engage themselves in the education of their students." Professor Mukherjee has been a long-time principal investigator of AFOSR, recognized for his pace-setting research on superplasticity, creep, and deformation mechanisms of advanced structural materials for engine and airframe applications.

Researcher Named Fellow of American Society for Metals and Materials

Dr. Donald A. Shockey, Director of the Metallurgy and Fracture Mechanics Department at SRI International (Menlo Park, CA) has been elected a 1993 Fellow of the American Society for Metals and Materials (ASM). This award is made annually to provide recognition of members for distinguished contributions in the field of materials science and engineering. Dr. Shockey was selected "for outstanding contributions toward the understanding of deformation and failure of materials under high strain rate loading." The award was presented during Materials Week, 18 to 21 October 1993 in Pittsburgh, Pennsylvania.

Dr. Shockey and his research group at SRI have been supported by AFOSR for over 10 years. His research has won international acclaim and added significantly to the Air Force's understanding of dynamic loading phenomena. Dr. Shockey's research relates to weapons effects and foreign object damage in aircraft engines and exposed surfaces, and has consistently been on the leading edge of fracture science.

Dr. Shockey's investigations have resulted in a number of breakthroughs in materials science. He developed a modification of classical static fracture mechanics to include time effects, making it possible to obtain a predictive fracture theory applicable to dynamic situations. He has also extended his research findings from idealized epoxy materials to metallic structural materials such as steels, titanium and aluminum alloys and done pioneering work on the incorporation of microstructural considerations in high strain rate failure. He is currently investigating the effect of interfaces on the dynamic failure of composite materials.

AFOSR Supported Graduate Student Wins Applied Mathematics Prize

Louis Rossi, a graduate student at the University of Arizona who has been supported by the Augmentation Awards for Science and Engineering Research Training (AASERT) program since its inception in 1991, was selected by the Society for Industrial and Applied Mathematics (SIAM) as one of four Student Paper Prize winners for 1993. Mr. Rossi's winning paper, a distillation of his doctoral thesis, was in the area of computational fluid mechanics. It described an innovative technique for incorporating viscous effects into the class of methods called vortex-blob simulations. This work had its origins in the effort to understand the generation of coherent structures in boundary layers which are important in predicting the performance of aircraft and jet engines. Mr. Rossi received a \$750 prize and presented his paper at the July 1993 SIAM annual meeting.

Aeroelasticity Expert Elected to National Academy of Engineering

Earl L. Dowell, Dean of the School of Engineering at Duke University, has been elected to the National Academy of Engineering. Professor Dowell was elected for his contributions to structural dynamics and aeroelasticity, which provide continuing insights into the behavior of complex structural systems.

Professor Dowell is an expert on the aerodynamics and structural dynamics of high performance aircraft. He has conducted many theoretical and experimental studies that have led to a better understanding of the nonlinear dynamic response of distributed systems under strong interactions between the aerodynamic environment and structural deformation. AFOSR first supported Dowell's research in 1981. In his current research for AFOSR, he is investigating nonlinear phenomena including high dimensional chaos, flutter and stall in order to develop "lower-order" models for the aeroelastic control of future Air Force high-speed, rapidly maneuverable fighters.

Prominent Researcher Elected to National Academy of Sciences

Professor Tobin J. Marks, who has conducted research on molecular composites and nonlinear optical polymers under AFOSR grants for more than nine years, was elected to the National Academy of Sciences this spring. Dr. Marks was elected to the Academy for his continuing contributions to chemistry. He is the Charles R. and Emma H. Morrison Professor of Chemistry and professor of materials science and engineering at Northwestern University. Marks, who holds 12 U.S. patents for various chemical processes, has a world-wide reputation in innovative synthesis methods. He is at the top of the list of most-cited researchers in the chemistry literature. He has given hundreds of lectures around the world on various aspects of his research and is engaged in a very wide range of research projects including polymer and solid state chemistry, nonlinear optical materials and catalysis.

Professor Marks has been a John Simon Guggenheim Memorial Foundation Fellow, an Alfred P. Sloan Fellow and received the American Chemical Society Award in Organometallic Chemistry in 1989. He is also associate editor of *Organometallics* and series advisory editor for Oxford Monographs on the Physics and Chemistry of Materials.

Physicist Wins International Science Prize

Professor Steven Chu, chairman of the Department of Physics at Stanford University, has been named the co-winner of the 1993 King Faisal International Prize for Science. He was accorded this honor for his work in expanding the frontiers of quantum optics by developing the techniques of optical cooling and trapping of atoms and using these techniques to perform experiments on positronium and muonium atoms. The Faisal prize is rotated each year among scientific disciplines and the physics prize is awarded every fourth year. At a ceremony held in Riyadh, the Saudi Arabian government presented each 1993 winner a cash award of \$93,333 dollars and a 22-carat gold medallion weighing 200 grams. Professor Chu's research in the techniques of optical cooling and the trapping of atoms has been supported by AFOSR since 1988.

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